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AUTHOR Seng, Tan Oon; Seng, Seok-Hoon
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ABSTRACT

This paper shares a cognitive intervention approach to teaching thinking to first-year students in engineering and applied science courses in Singapore. The theoretical underpinnings of the Cognitive Modification Intervention (CMI) are based on Feuerstein's Theory of Structural Cognitive Modifiability. Embedded in this theory is the Theory of Mediated Learning Experience, which propounds that the quality of interaction between a learner and an intentional human play a significant role in the cognitive development of the learner. The design of the intervention includes a diagnostic approach for attacking cognitive deficiencies through self-awareness and metacognitive activities; cognitive modification through mediation learning; and bridging and use of thinking tools for effective transfer across academic and life situations. The study used four experimental and four control groups, with 18-20 students per group who participated in the intervention. Although the quantitative results of the pre- and posttests are not yet fully analyzed, the subjective experience of the mediator and qualitative feedback from the participants are encouraging. The results lend support to the school of thought that thinking can be taught and that intelligence is modifiable. (SM)

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TEACHING THINKING FOR ENGINEERING AND APPLIED SCIENCE STUDENTS: A COGNITIVE MODIFIABILITY APPROACH

Tan Oon Seng
And
Seok-Hoon Seng
National Institute of Education
Nanyang Technological University
Singapore

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Abstract

Unprecedented breakthroughs in technology and constant changes in many aspects of life point to the need for individuals to be able to adapt and function effectively in fast changing environments. Educators are therefore challenged more than ever before with the need to develop students who would be active, self-motivated and independent thinkers. Since the beginning of this decade Singapore has embarked on a policy of rapid expansion in polytechnic education. A corollary of this is the rising challenge of helping a much larger number of students with learning and coping problems at the post-secondary level. How can we help these students in thinking and learning skills?

This paper will share on a cognitive intervention approach in teaching thinking to First Year students in Engineering and Applied Science courses. The theoretical underpinnings of this intervention are based on Feuerstein's Theory of Structural Cognitive Modifiability (Feuerstein et al,1980).Embedded in this theory is the Theory of Mediated Learning Experience which propounds that the quality of interaction between a learner and an intentional human being can play a significant role in the cognitive development of the learner.

Armed with the hope that "the human organism is open to modifiability at all ages and stages of development" the design of the intervention includes: (a) a diagnostic approach for attacking cognitive deficiencies through self-awareness and metacognitive activities; (b) cognitive modification through mediation learning and (c) bridging and use of thinking tools for effective transfer across academic and life situations.

This presentation will also provide a demonstration of sample components of the intervention as well as a sharing of some preliminary findings.

INTRODUCTION

As we approach the 21st century the role of education has often been described as that of bringing about a generation of thinkers. The year 2000 and beyond signals an era of unprecedented breakthroughs in technology and constant changes in many aspects of life. There is thus a need for individuals to be able to adapt and function effectively in fast changing environments. Educators are therefore challenged more than ever before with the need to develop students who would be active, self-motivated and independent thinkers.

In Singapore the concern for teaching skills in thinking have become the major agenda for education in recent years. The need to move away from the current emphasis on mastery of content to one that will give students greater opportunities to acquire thinking skills has been repeatedly mentioned. Since the beginning of this decade Singapore has also embarked on a policy of rapid expansion in higher education. Opportunities for polytechnic education, in particular, will be doubled by 1998. Between 1990 and 1998 the number of polytechnic students is expected to increase from 24,000 to 48,000. This means that many academically weaker students are now given opportunities for higher education. An implication of this change in policy is the rising challenge of helping a much larger number of students with learning and coping problems at the post-secondary level. A common concern amongst polytechnic educators is that these students need help in thinking and learning skills.

In more developed countries like the United States the importance of teaching thinking has been much emphasized since the 80s (Costa & Lowery, 1989). Whilst there is quite a plethora of research and literature on cognition the need as pointed out by Robert Glaser in his preface to the two volumes of *Thinking and Learning Skills* (Segal et al 1985) is "to design instructional programmes" that successfully teach "higher cognitive skills".

There are a number of important considerations when studying a thinking programme. First the theory on which the intervention is based. Then we must consider the assumptions built into the programmes about the nature, development, and acquisition of thinking and learning skills. Feuerstein's work (Feuerstein, et al, 1980) is probably one of the few thinking programmes with a comprehensive theory and well supported empirical evidences.

Feuerstein's Theory of Structural Cognitive Modifiability (Feuerstein et al, 1980; Feuerstein et al , 1991) has indeed been gaining acceptance amongst both educators and researchers. His theory gives hope that "the human organism is open to modifiability at all ages and stages of development." Embedded in the Theory of Structural Cognitive Modifiability is the Theory of Mediated Learning Experience (MLE) which propounds that the quality interaction between a learner and an intentional human being can play a significant role in cognitive development of the learner.

Feuerstein's faith in the modifiability of intelligence is demonstrated in his almost half a century of continuous work and research that has resulted in his popular intervention programme known as the Feuerstein Instrumental Enrichment (FIE) programme

(Feuerstein et al , 1980). The ultimate aim of FIE is to transform low performers by altering their characteristically passive dependent cognitive style so that they become more active, self-motivated and independent thinkers.Whilst the FIE programme in its entirety has been effective for use with low functioning adolescents its use with other population groups appears to require modifications and improvements.

THE CMI RESEARCH

This research attempts to design a thinking programme known as the Cognitive Modification Intervention (CMI) programme based primarily on the theory propounded by Feuerstein. The purpose of this study is firstly to develop a thinking programme for polytechnic level students based on Feuerstein's theory of structural cognitive modifiability and mediated learning experience as well as the principles of cognitive intervention used in Feuerstein Instrumental Enrichment programme.

Secondly this study seeks to investigate the effects of the intervention developed on the attitudes, problem solving abilities and achievement of polytechnic students.

THE RESEARCH DESIGN

The CMI research is a rather extensive project involving the development, adaptation and design of a 30-hour thinking programme spread over a full academic year. The participants thus receive a one-hour lesson each week of intensive activities and interaction over a period of 30 weeks.

The major research questions are:
1. What are the effects of the CMI on attitudes of polytechnic students?
2. What are the effects of the CMI on cognitive abilities of polytechic students?
3. What are the effects of the CMI on achievement of polytechnic students

A quasi-experimental design was employed involving four experimental groups and four control groups. The pre-post test design involved 4 matched groups each experimental which were assigned through a stratified random sampling which assigned the matching based on key "O" level results which was the basis for the admission of the students. There were 18-20 students for each group. Two of the experimental and two of the control groups involve students of an engineering course. The other two experimental and two control groups involve students from an applied science course.

The dependent variables were defined operationally through measures from selected scales and subscales of the following instruments:

- The Learning and Study Strategies Inventory
- The Cognitive Abilities Tests
- Achievement Tests in the respective engineering and applied science curricula

THE SCOPE OF THIS PAPER

The purpose of this paper is to provide the rationale and scope of the research project as described above and to demonstrate the applicability of Feuerstein's work to the context of polytechnic students in Singapore. The more extensive data analysis of the quasi-experimental design will not be dwelt with in this paper. What the researcher will do in this symposium is to illustrate how various scenarios of learning in the polytechnic settings point to the critical need to address cognitive functioning and then provide an overview of the intervention. Some preliminary results from the feedback of participants in the programme will also be shared.

OBSERVATIONS AND REFLECTIONS ON SCENARIOS OF COGNITIVE FUNCTIONING IN POLYTECHNIC LEARNING ENVIRONMENT

The following cases represent typical scenarios that occur in the polytechnic setting where students are involved in various learning situations. The researcher's insights and reflections were gained indirectly and informally through his role as a teacher-educator for the training of polytechnic lecturers where he had been involved in the observation of teaching. The researcher has observed some 100 or more lessons in the last five years of his role as a staff developer. Instead of focusing only on the teacher, however, his foremost question in every observation is "what is the quality of thinking going on in the minds of students?"

Scenario One

In an engineering class, the students were involved in solving logic circuits. When presented with a diagram involving various logic gates, some students failed to observe the instructions given and went straight into constructing a "truth table". (The instruction was to simplify the circuit.) In several instances, some students simply asked for the final solution and then used trial-and-error methods to arrive at the solution. The better students, however, checked the instructions, planned the way they would approach the problem and solved the circuit systematically either from top to bottom or from one end to the other. For those who did not learn the topic well was it a problem of lack of understanding of the content? Of course, it was necessary to know the facts such as which symbol corresponds to which type of gate and what are the particular features and functions of each gate. But having memorised and learned these a number of students still had a great deal of difficulty. Then there were those who could do simple 2-step or 3-step problems especially when very similar examples were given for them to model after. But when there were multiple steps that required the simultaneous handling of a few varying factors some students gave up. Then there were those students who thought they understood the principle but perpetually made mistakes in many steps of their solution. When the lecturer analysed their solutions together with them there would always be some inaccurate substitutions or mistaken perceptions. Very often such a student would simply be told "you tend to be very careless - you need to be very careful and meticulous in solving this kind of problem." A student even responded with these words: "since primary school every teacher has said I am careless. That's why I just managed to pass my O levels."

The problem as the researcher noted is not just one of dealing with the content or knowledge involved. It even goes beyond emphasizing the "process" aspects of working with the knowledge. Something needs to be done about the students' thought processes. Something is lacking in the mental functioning. Some patterns and habits of thinking have to be changed if the students would become more efficient learners and better problem-solvers.

Scenario Two

In a practical session on audio-related circuits students were required to locate and identify possible faults and locate the components that were not functioning. A number of students started using various meters and the oscilloscope to tap on various parts of the circuit. The trial-and-error attempts were rather erratic. Some of them became very frustrated with their attempts when they did not seem to get anywhere. In another group, one of the members immediately focused on one area and insisted that the fault was very likely to start there. It appeared that there was a fault there but the problem was not so localised. The other members then insisted that it was also important to consider the circuit as a whole and not just zoom in so impulsively. In another group the students sat down to plan and make a list of the most common faults and then proceeded somewhat systematically.

What can we say about the impulsive behaviour of students in their attempt to solve a problem? How is it that some students have developed better mental habits of planning and making strategies? Are some of these students aware of tendencies to react impulsively? What about those who never have a habit of being systematic? And what about the student who insisted on his narrow perception of the problem location and refused to look at the "big" picture first?

Scenario Three

In an engineering workshop practical session on "air-conditioning and mechanical ventilation" students had to locate leakages. Figure 1 shows the steps given to them. A number of students tried to follow the procedures given in a systematic fashion. Some students were rather impatient - jumping a number of these steps. Others repeatedly ignored certain precautions although they were aware that these should be followed. When asked why they did not follow every step some of them remarked that they knew what to do and would "go back" to the precautions if necessary. What kind of habits and patterns of thinking will they practice in real life situations when they have to repair such systems? In fact one could extrapolate further and raise the question on the problem of why despite quality procedures in place there is often still a high degree of wastage resulting from poor fittings, failure to meet tolerence limits and so for at manufacturing plants and factories. What can we do to intervene so that our polytechnic graduates will be good technicians and effective workers for the future.

Scenario Four

In an applied science course on computer programming the students are required to develop programme lines and algorithms. Figure 2 illustrates a sample of such programme lines.

Students were often frustrated when the programme eventually did not work. Very often the students who had worked hard at the programme discovered that it was just one word or punctuation missing or sometimes an extra word that created the "bug". Would it have helped if some of these students who frequently encounter failure in their programme would developed better habits of mind such as being systematic and being precise in gathering data and in outputting of their programme lines?

Scenario Five

In a biotechnology class students had to identify various strands of bacteria under a microscope. Some students were able to classify correctly and provide very detailed explanation of the characteristics and features they observed. In a class on food chemistry when looking into identification and recognition of emulsifiers, stabilisers and flavourings students found that they had to do a lot of classification. Some students were more successful than others in working on classification. What mental functions are involved in doing classifications?

Scenario Six

All final-year polytechnic students had to be involved in a final-year practical project that represented the integration and application of their learning. The project would ideally be an innovation with potential for industrial application or commercial replicability. Groups of students were at work on their projects and had to submit their project proposals. Individual and group projects were allowed. When observing students at work for their projects some students appeared totally at a loss for ideas. Even when some ideas and starting points were provided by their lecturers, students would ask how else could they ever improve an existing design. How can we help students in their thought process to break though "lock in" perceptions? How can we helped students to come up with creative ideas?

The scenarios that have been described and the researcher's occasional reflections and observations point to the fact that in helping students to learn effectively there is a critical need to address not just the content and process skills related to a topic or subject but also the cognition of the students. In spite of the diverse fields and topics at the polytechnic setting there are a number of cognitive functions that are crucial for successful thinking. These cognitive functions of students relate to various aspects of cognition such as the planning behaviours of students, accurate and non-sweeping perception, systematic exploratory thinking, simultaneous handling of various sources of information and broadness of mental field.

Can we have an intervention programme that will help students think better?
How will the intervention programme address the cognitive functions (such as accurate elaboration of data)? How could the teacher as a mediator facilitate the identification of possible deficient cognitive functioning and bring about a change in the cognitive patterns of the learners? Is there a sound theoretical basis and other empirical research that support such an intervention?

When the researcher first came across the work of Professor Feuerstein documented in two books, namely, *Instrumental Enrichment: An Intervention Programme for Cognitive Modifiability* and *Mediated Learning Experience (MLE): Theoretical, Psychological and Learning Implication* he was deeply impressed by the potential application of the theory towards diverse populations. The application of the theory to a thinking programme for polytechnic level students would represent a highly appropriate and much needed extension of the "technology" implied and provided by Feuerstein. This research represents an advancement of the application of the theory of structural cognitive modifiablity and mediated learning experience in the polytechnic setting and in the Asian (in particular, Singaporean) cultural context.

THE DESIGN OF THE INTERVENTION: AN INTRODUCTION

Whilst Feuerstein's theory provided the theoretical foundation for this intervention it should be noted that in documenting this research the author has reflected on the details of the application and re-interpreted many of the terms used by Feuerstein. The broad framework of the theory remains but what is described represents an innovation in the intervention. The researcher's focus is on the principles rather than the content and procedures related to the instruments found in Feuerstein's instrumental enrichment package.

In designing the intervention the researcher has based on pilot trials selected those instruments (materials) from the FIE package that would be most relevant in his context of intervention. A large variety of thinking activities, however, have been adapted from various sources and new designs added by the researcher to constitute this new training package.

The design of the intervention is intimately woven with the theory of structural cognitive modifiability. The mediator's underpinning belief is that the existing cognitive structure of the learner can be modified. We also assert that the capacity to be modified can be increased. The mediator also plays a critical role in helping learners into this positive belief system - that their cognitive structure can be positively modified and hence they can become better learners and thinkers. The affective-motivational domain which relates to the cognitive domain of the individual is the first line of attack in the intervention, following which the learner is involved in working on a number of thinking activities which provide the vehicle for dynamic assessment and mediated learning experiences. The quality of interaction in the mediation plays a critical role in affecting the cognitive structure of the learners.

The broad goals of the intervention are that by the end of the intervention the students will

1. Gain a better understanding of their abilities to increase their thinking and learning capacities.
2. Gain a better understanding of their cognitive functions and how these may be further developed, refined and crystallized for effective thinking
3. Gain greater awareness and insights into their own level of awareness, thinking habits and patterns and attitudes
4. Become more reflective and insightful learners

5. Correct their weaknesses and deficiencies in the various cognitive functions and dimensions of thinking
6. Produce sound and positive thinking habits and patterns resulting from more effective cognitive functioning
7. Become more active, self-motivated and independent learners and thinkers as a result of cognitive modification
8. Become more active generators of new information and more creative thinkers as a result of cognitive modification.

In a typical lesson, we can describe three components of the intervention. These are

- The Meta-Awareness Stage (Diagnostic Approach)
- The Learning Stage (Mediation Approach)
- The Bridging and Application Phase (Empowerment Approach)

These stages of the intervention are best summarised by reference to the Cognitive Functions Disc (CFD) and the Repertoire of Mediated Learning (RML) which the researcher has synthesized from the work of Feuerstein for context of teaching thinking for polytechnic students.

COGNITIVE FUNCTIONS DISC (CFD)

The intervention is directed at eliminating deficient cognitive functions in the individual (resulting from previous lack of positive mediated experiences and other antecedent factors) and enhancing the cognitive functions and overall cognitive operations. In our intervention the concern related to the aetiology of factors like socioeconomic background, environmental stimuli, genetic factors, maturation and cultural differences are secondary as these are distal factors to our intervention. That which is proximal is the quality of mediation in the intervention that can provide the learner with experiences that will alter and enhance his/her cognitive structure.

Our earlier discussion has highlighted the fact that where manifest performance is lacking in various learning situations related to acquisition of academic, technical or professional skills we cannot simply attribute it to a lack of content knowledge or the lack of understanding of the principles involved. As Feuertein noted, it is even worse to attribute failure to perform to low intelligence.

As in one of the earlier examples mentioned, failure to handle a fault finding exercise in an audio circuit could be the result of implusive patterns of thought where there is poor planning behaviour and erratic trial and error attempts. Sometimes such manifest behaviours appear consistently in specific or even across various situations for that individual. Whatever the content of thought he/she is involved with there appears to be deficiencies in the internalized, representational or operational pattern of thought.

Good habits of planning and systematic exploration are related to cognitive functions that are prerequisites of good thinking and problem-solving. In our intervention our concern and focus is to attack the deficient cognitive functions and current patterns and habits of thinking that are clearly weak or contrary to effective thinking. We seek to modify these patterns, increase the flexibility and capacity.

The identification of a framework and reference of deficient cognitive functions is essential to help the mediator address such cognitive functioning. The researcher has designed what he calls a cognitive function disc (CFD) as shown in Figure 3 which summarizes a list of cognitive functions that would be addressed in the intervention. The disc is the result of a synthesis and merging together of what Professor Feuerstein has expounded vis-a-vis the practical context of learning in the polytechnic setting.

The lessons and various materials and tools used in the intervention address various groups of cognitive functions shown in the disc. Like Feuerstein's lists the functions in the disc are by no means definite or exhaustive. The functions are also not mutually exclusive but simply served to provide the focus of diagnose and dynamic assessment for a particular lesson in the cognitive modifiability intervention.

At the inner most ring we have the "affective-motivational" dimension. We shall use the phrase "affective-motivation" to encompass the whole range of attitudinal factors which combine to influence cognitive processes. In fact right from the start and at every stage of the intervention attention has to be paid to this dimension. The principles of mediated learning in the subsequent section of this paper will further illustrate how the lesson would include elements that address such positive attitude development. In the next ring we borrow a simple information-processing model to consider the various cognitive functions of a mental act. We have the input, elaboration and the output phases. These again is an artificial allocation and not meant to be absolute distinction. Most importantly we have the cognitive functions which we seek to address. In a typical lesson such as the first few lessons entitled Organisational Thinking I, II and III we focus on cognitive functions such as clear perception, precision and accuracy in gathering data, planning behaviour, restraint of impulsivity and so on. The materials and instruments include selections from FIE's organisation of dots and several thinking activities provided by the researcher. Whilst the design of the materials require tremendous preparation and thought our focus is the use of these materials as a "means" or "tools" to effect on those cognitive functions we aim to address. The thinking activities have been deliberately selected to naturally allow the mediator to focus on the processes of thinking rather than the content. Activities and materials used are therefore content-free, non-routine or novel problems.

REPERTOIRE FOR MEDIATED LEARNING (RML)

We will outline the characteristics of mediated learning experience (MLE) in the context of this intervention as applied to polytechnic education. The cognitive function disc (CFD) provides a focus for the facilitator (mediator) to concentrate on the quality of thinking in the learners, that is, what is going on in the minds of the learners in terms of their cognitive processes and functioning. Knowing what is in the cognitive structure of the learner and what we hope to modify and enhance in the learner's cognitive structure is only one side of the coin. The other side of the coin is the behaviours and what is going on in the mind of the facilitator that will bring about a quality mediation resulting in effective learning. In looking at the intervention from the point of the mediator we shall use a repertoire of parameters that has again been carefully put together by Feuerstein and his team. Many of these parameters characterised good pedagogy, didactics and facilitation skills. It should be emphasized, however, that what is in the mind of the mediator would be those qualities of the

interaction that would be most important to the modification of the cognition structure of the learner. We shall call these sets of parameters the "repertoire for mediated learning" (RML) as shown in Figure 4.

This first ring of the RML comprises the following:

1. Intentionality and Reciprocity
2. Mediation of Meaning
3. Transcendence

Intentionality refers to the deliberate intention and the purposefulness of the mediator in guiding the interaction towards specific learning. How can one teach thinking processes without the clarity of his intention and goals? The mediator has the end in mind and proceeds enthusiastically to share and elicit participation. In the case of our intervention this calls for preparation and a keen awareness of the cognitive functions that could be addressed. The mediator however also bears in mind that his intention must be matched by the responsiveness and receptiveness of the learner. The quality of the interaction is critical in ensuring the effectiveness of any intervention.

A mediation must also be characterised by a clear communication of the meaning and significance of the thinking activities. The learners are helped into appreciating and understanding the value of the activities. Meaning is critical in motivating and energising the learner. The mediator must be capable of giving reasons for the activities and demonstrating his own beliefs and value system as he attempts to fire-up the interest of the learners.

Transcendence refers to the bridging, transfer, diversification and extrapolation of immediate experiences in the activities to related issues and activities. The mediator thus promotes the acquisition of principles, concepts and strategies to be generalised across a variety of situations where the cognitive functions in particular would be employed.

Intentionality and reciprocity, meaning and transcendence are essential ingredients in any CMI lessons.

Apart from these three parameters, the following parameters were incorporated as far as possible at various lessons and were covered by the total programme. These are in the second ring and include:

Mediation of

- Feeling of Competence
- Interdependency
- Individuation
- Goal Seeking, Setting and Achieving
- Challenge (Novelty and Complexity)
- Self-Change
- Search for Optimistic Alternatives
- Feeling of Belonging
- Reflective Practice

BRIDGING AND APPLICATION IN CMI

Bridging refers to the transfer and application of the cognitive processes and functions involved in the CMI lessons to specific subject-matter areas. The whole CMI programme has been designed with a consideration of the relevance of the theory of cognitive modifiability in the light of the kinds of thinking skills required in various polytechnic curricula. The curriculum may involve academic situations, acquisition of technological knowledge and skills, problem solving and simulation of real-life situations as illustrated by the scenarios given at the beginning of this paper. Bridging to specific subject-matter area is thus a natural corollary of the intervention.

Although the polytechnic students participating in the programme were at a level where they could on their own transfer the learning to the learning of their curricula and real-life situations it is an integral part of the intervention to emphasize the applications of the CMI lessons to ensure the development of insights and bridging to content learning and various contexts. This is often done through good didactics and pedagogy that encourage the students to work in pairs and groups to discuss how they have been helped in the lesson and how they could apply the learning. The mediator then summarizes examples of applying the awareness gained, the learning of specific cognitive functions, extrapolation of the learning as well as the need to consciously practise the positive and productive habits of thoughts.

SOME PRELIMINARY FINDINGS

The researcher in his attempts to put into practice Feuerstein's theory must acknowledge that it has been a most educational and rewarding experience albeit a very intensive one. The researcher himself has been the mediator for all the four treatment groups. The detailed study of Feuerstein's work, an intensive training with Feuerstein and his team, adapting, designing and piloting the lessons and finally implementing the intervention took three years of rather intensive work. Although the quantitative results of the pre and post tests are yet to be fully analysed the subjective experience of the mediator and qualitative feedback from the participants have been most encouraging.

The following are samples of what students commented (unedited) about the CMI:

Thinking programme has made a lot of us aware of the importance to think. This involves planning (give yourself time to think), use of strategies, and setting your priorities right first... In this way this would help us in making better decisions in our life.... After knowing all these different techniques about thinking my way of thinking has naturally practiced this actually. Better decisions were made at important times."
KT, F11C

It change my thinking patterns and attitudes. I think more systematically, search for sources of error and use strategies, look for different perspective when solving problems.
AB, F11B

Helps to visualise problems more clearly and how to solve them.. to work quickly and systematically with accuracy. And also helps to build a strong character..
It made me more commited to correct my problems and not to give up so easily…
TL, M110

The programme gives me another window to my mind that I didn't knew exists. I am able to think things thoroughly and not jump into rash reaction when solving a problem. I am able to set priorities so as to when I should start my project and materials needed and ending it correctly.
FW, M112

Help me begin to see things in different angle, look for more alternatives for problems, restraint from impulsiveness, know how to set priorities, think of a strategy begin to plan properly/systematically.
LW, F11B

I've changed my ways of thinking towards study and I planned everything well ahead.
AR, M112

I learn to solve things in the lab where you learned to do things step by step and also the problem..
KW, M112

It thought me that many time problem can't be solved within itself but also from other aspects. I also learn that metal block could be solved and thus helped me a lot.
KM, M112

By doing some of the thinking exercises our mind will be working and brainstorming for solutions. Therefore when we really need to think we are able to do it properly.
YH, F11B

I tend to do some planning before I get started. I also refrain myself from wrongful assumptions.
PKM, F11C

What I learn:
different people look at things differently,..they think differently
become more open-minded..look at things differentlly..never to judge things on the first impression.
YYH, F11C

It helped me to think beyond my se perspective of thought, to think further, and not to set a limit of possibilities.
GPE, F11C

Thinking programme has made me think wide, make me get to know my mistake of the way I think … It also makes me more determine to conquer difficult problem.
EB, F11C

I think it has helped me to think gradually .. to think of an object beyond its purpose.
JN, M110

It has made me less impulsive and less likely to jump to the first conclusion that I arrive on.
DC, M110

It has taught me to be more flexible in thinking and the importance of determination in achieving goals. It has taught me a systematic way of thinking and looking at and solving problem.
SL, F11C

I now think before I do anything. I set my priorities and plan properly before doing anything. I also learn to think further... stretching my imagination. I also learn to be more determined.
JT, F11C

I must admit it really help me to "see" things from a clear and better angle ...I use to think in one track mind.
CBS, M112

It has helped me to link very thing we learn and help me to see problems in a different way for faster solution finding... It has changed the way I tackle a problem.
SG, M112

I recommend that polytechnic student should go through the programme because it will allow them to understand themselves better and allow them to overcome problems.
KK, M110

The researcher's experience is that most if not all of the students in the experimental groups have been much helped as indicated by the above testimonies.

CONCLUSION

It appears that the potential effectiveness of this Cognitive Modifiability Intervention as a thinking programme for polytechnic students is very promising. It has been the hope of the researcher that this study would be major contribution in our national quest for our polytechnic students to be better thinkers, good problem solvers and more creative professionals. In terms of advancing the frontier of knowledge in the field of the theory and practice of teaching thinking this study is significant, despite several limitations, in the following ways.

Firstly, from the broadest perspective it lends support to the school of thought that thinking can be taught and that "intelligence" as defined in this study is modifiable and hence adds faith and hope to researchers and educators world-wide in their quest to improve the thinking and learning of people at all ages - in particular at the college and polytechnic age group.

Secondly, this study is an application of Feuerstein's theory of cognitive modifiability and mediated learning and helps to extend the applicability of the theory to a wider population. Thus far there has been no known research on Feuerstein's work for the college/polytechnic level in Asia. Even in the West, research on the application of Feuerstein's work to college population are few in number although much work has been documented on adolescent groups. Some research on application FIE to school children as well as pre-service teachers have begun in Singapore and this study will give a fuller picture of the applicability of Feuerstein's work for Singaporean learners.

Thirdly, in relation to the application of Feuerstein's work to Singapore and this part of the world the study represents an extension of Feuerstein's work across cultures. The Asian culture has traditionally been recognised as different in many ways from the West. Cultural transmission plays an important role in terms of the antecedent factors determining a person's cognition and hence it is most interesting to study the effects of the application of Feuerstein's work in the Asian context.

Fourthly, the contribution is in answer to the question of what Feuerstein's theory and his principles of intervention claim to modify. Previous studies have documented effects on various aspects of attitudes, problem solving abilities, cognition and meta-cognition. This study provides further insights into the effects of such intervention and throws light on the modifiability of these attributes. These include the effects on various aspects of attitudes, verbal intelligence, quantitative intelligence, flexibility of thought and the effects on achievement of the professional knowledge and skills required in polytechnic training.

Last not least, the researcher and the participants have themselves felt the effects of experiencing cognitive modifiability in a most positive way and this will impact on both themselves and the people they interact with. The very belief in the underlying principles and philosophy of modifiability of the human being continues to give faith, hope and joy to many more.

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Figure 1: Sample of instructions for checking for leakages in a workshop

a. Set up the vacuum pump and the gauge manifold as in Figure 4.
b. Close the valve assembly to isolate the compressor from the vacuum pump.
b. Operate the vacuum pump with the "Lo" knob open and the "Hi" knob closed.
c. Check the gauge for the readings to stabilise at 10 mmHg abs.
d. Close the gauge manifold and stop the vacuum pump.
e. Crack open the valve connecting to the nitrogen bottle.
f. Gradually open the valve in stages to introduce a pressure of 13.5 to 17.5 bar.
g. Use soap solution to check leakages at joints of copper piping.
h. Isolate the nitrogen bottle from the system.
i. Operate the vacuum pump to extract the nitrogen from the refrigerant piping.
j. Check the gauge for the readings to stabilise.
k. Close the gauge manifold and stop the vacuum pump.
l. Record the weight of the refrigerant cylinder before charging.
m. Calculate the expected new weight of the refrigerant cylinder base on the amount of refrigerant to be charged as recommended by the manufacturer's.
m. Open the valve connecting to the refrigerant cylinder.
n. Shut the valve when the change in weight is indicated on the weighing scale.

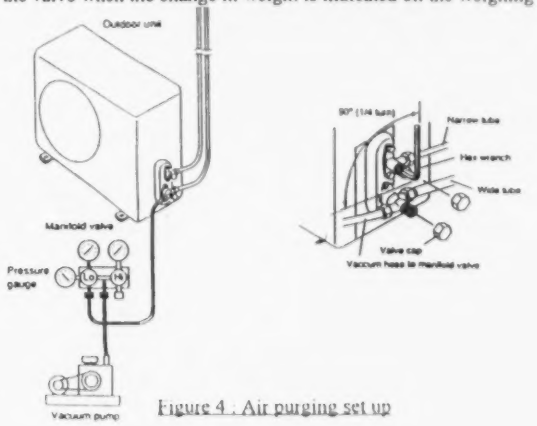

Figure 4 : Air purging set up

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Figure 2: Sample of writing of programme lines in an information technology and applied science class

```
        if(select==0)
          for(i=0;i<count;i++)
            printf("\n%-3d. %-40s $%.2f",i+1,books[i].title,
                    books[i].price);
        else
          printf("\n%-3d. %-40s $%.2f",select,books[select-1].title,
                    books[select-1].price);
        break;
      }
      else
        printf("\nInvalid entry!  Please try again ...");
    }
    return;
}

void modify()
{
    int i, select, count=0;
    rewind(fp);
    while(fread(&books[count],sizeof(struct blist),1,fp)) count++;
    printf("\n\nTotal no. of records = %d", count);
    while(1){
      printf("\nPlease select record no. to modify : ");
      scanf(" %d",&select);
      if(select>0&&select<=count){
        printf("\nRecord no. : %d", select);
        printf("\nBook title : %s", books[select-1].title);
        printf("\nBook price : $%.2f", books[select-1].price);
        printf("\n\n[Blank line to preserve old title]\nType new title : ");
        fflush(stdin);
        gets(temp.title);
        if(temp.title[0]!=0)
          strcpy(books[select-1].title,temp.title);
        printf("[Enter 0 to preserve old price]\nType new book price : $");
        scanf(" %f",&temp.price);
        if(temp.price>0)
          books[select-1].price=temp.price;
        break;
      }
      else
        printf("\nInvalid entry!  Please try again ...");
    }
    fseek(fp, (select-1)*sizeof(struct blist), SEEK_SET);
    fwrite(&books[select-1], sizeof(struct blist), 1, fp);
    return;
}

void add()
{
    printf("\nNEW RECORD.");
    printf("\nEnter new book title : ");
    fflush(stdin);
    gets(temp.title);
    if(temp.title[0]==0){
      printf("\nInvalid title!"); return;
    }
    printf("Enter new book price : $");
    scanf(" %f",&temp.price);
    if(temp.price<0){
      printf("\nInvalid price!"); return;
```

Figure 3: The Cognitive Functions Disc for Cognitive Modifiability Intervention (CMI)

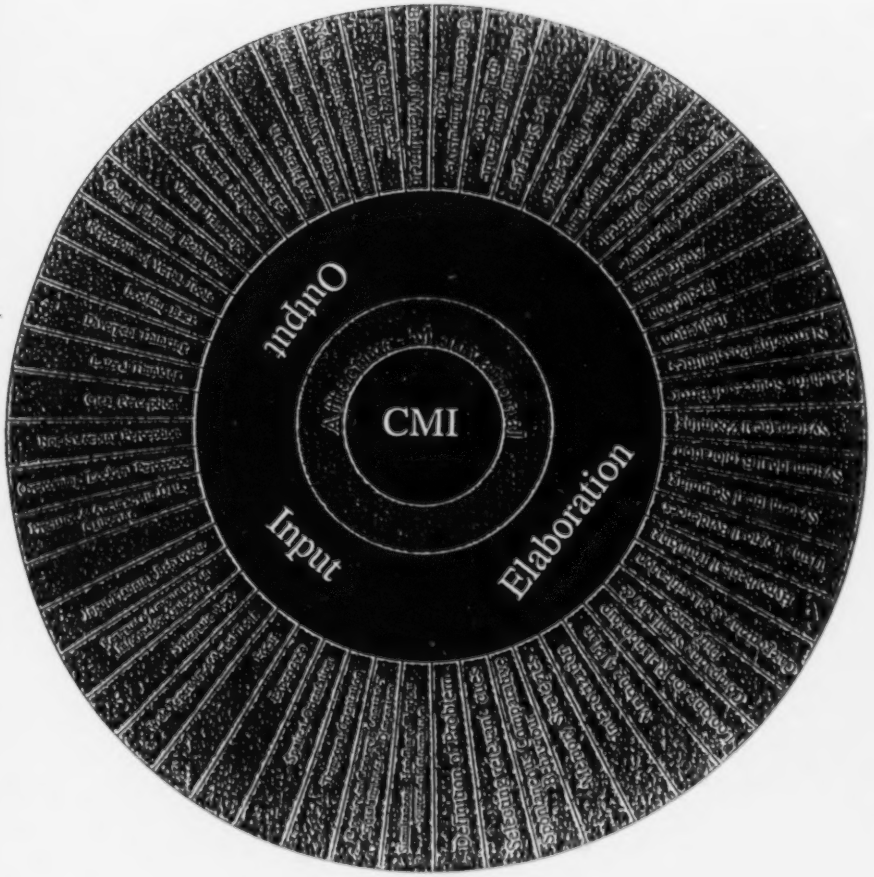
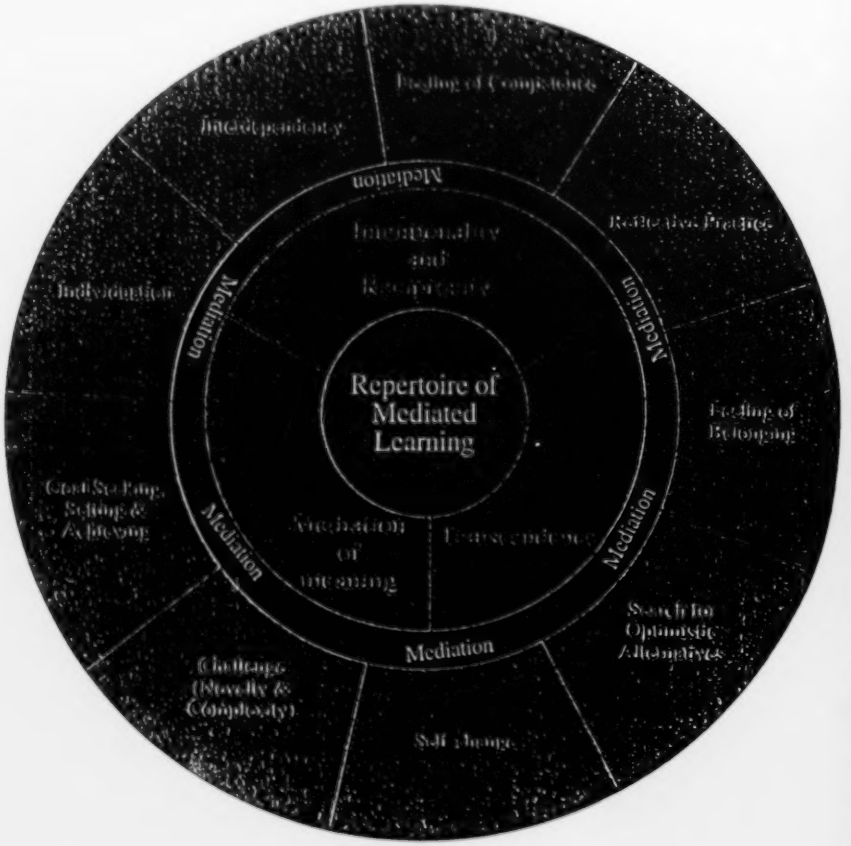


Figure 4: Repertoire of Mediated Learning


Repertoire of Mediated Learning
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